

Feb. 1, 1966

D. E. ROBINSON
DUAL WIRE TYPE PAPER-FORMING APPARATUS AND
METHODS OF FORMING AND DEWATERING PAPER

3,232,825

Filed Sept. 16, 1963

6 Sheets-Sheet 1

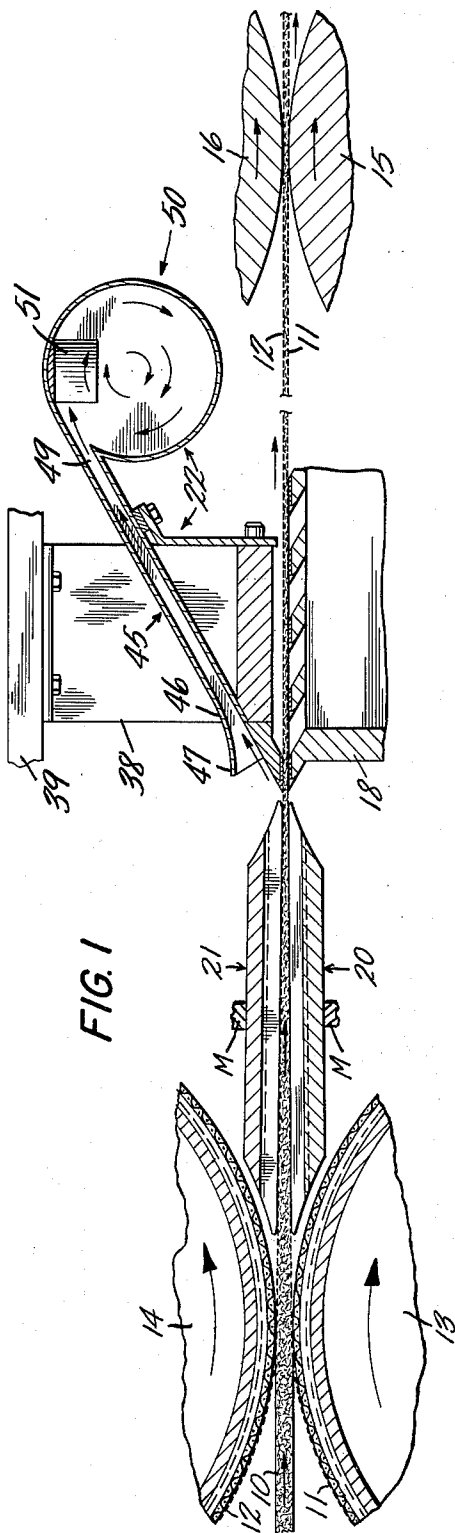


FIG. 1

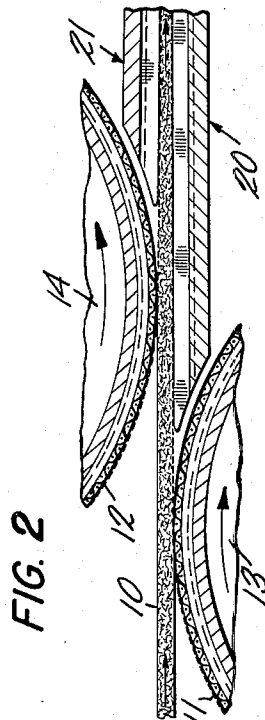


FIG. 2

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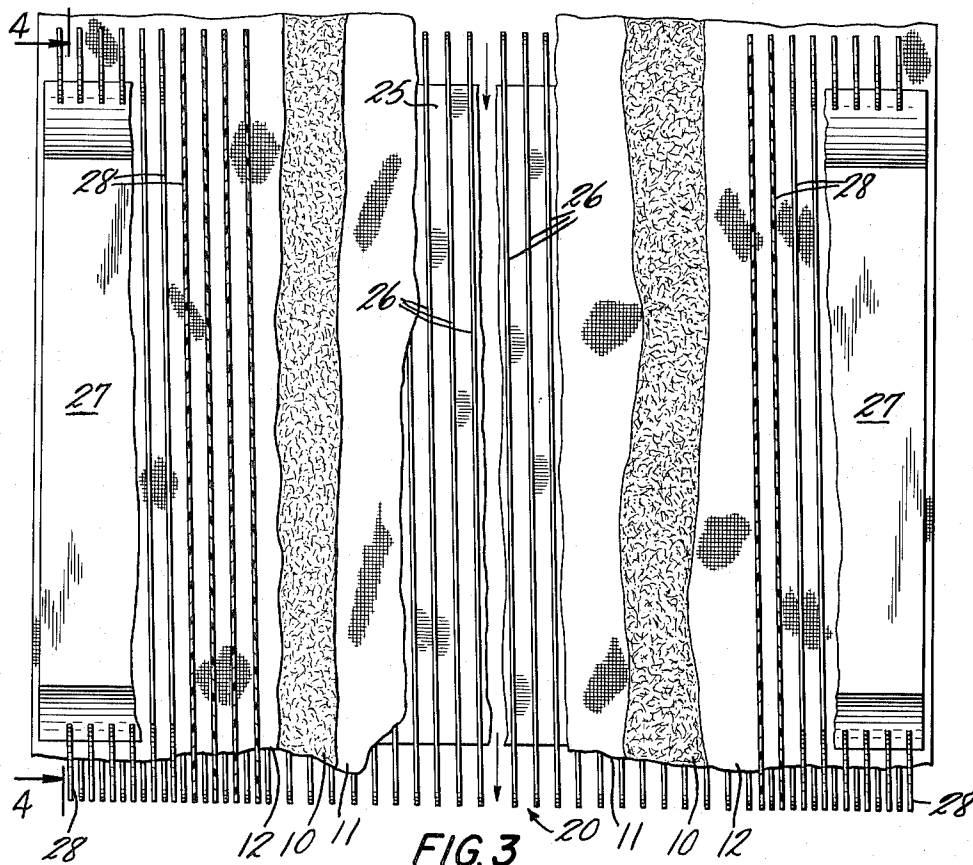
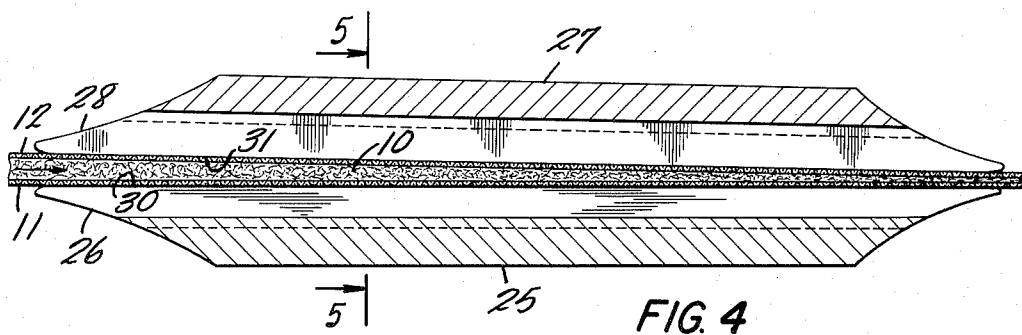
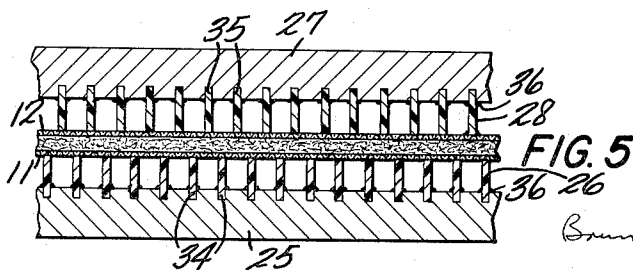
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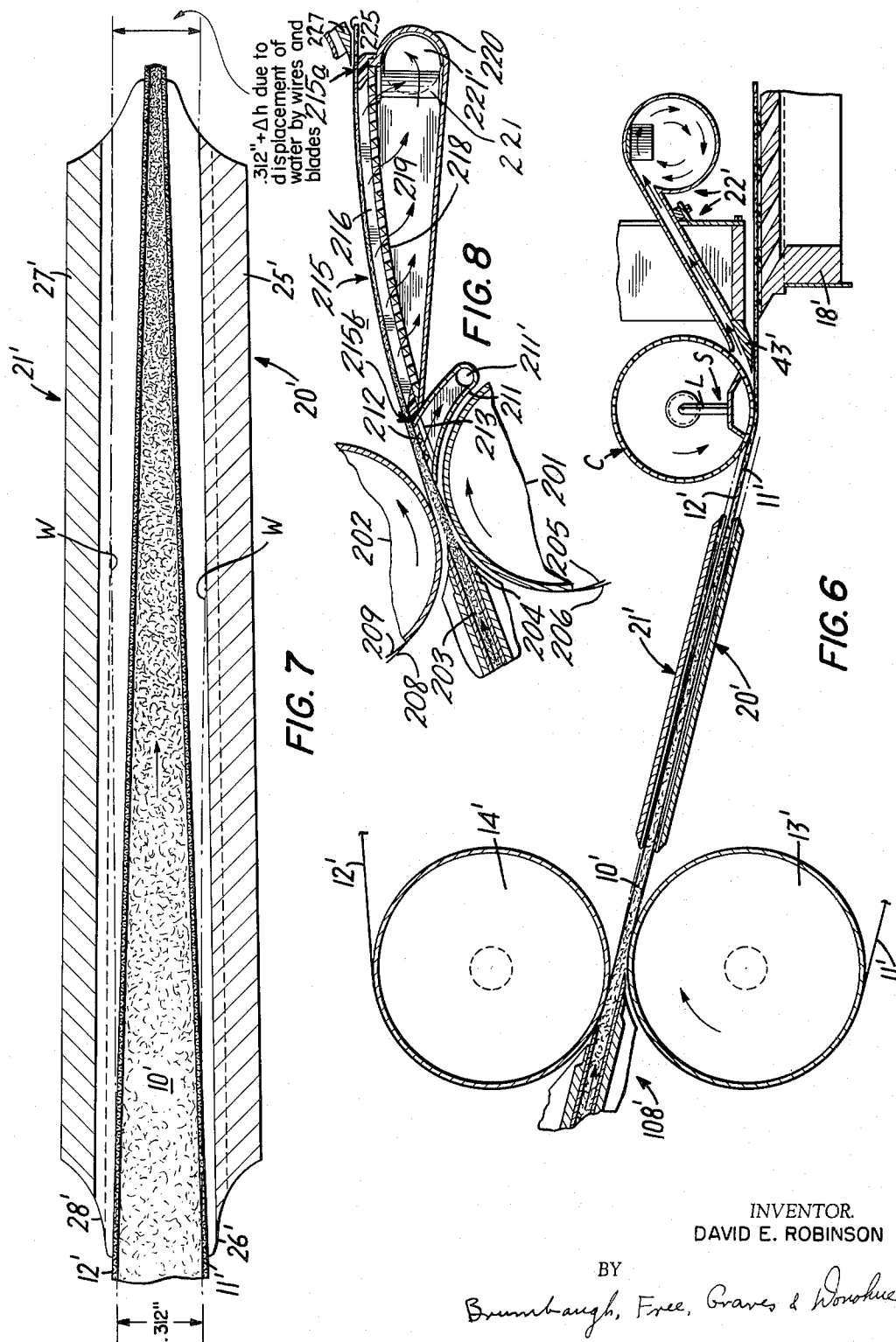
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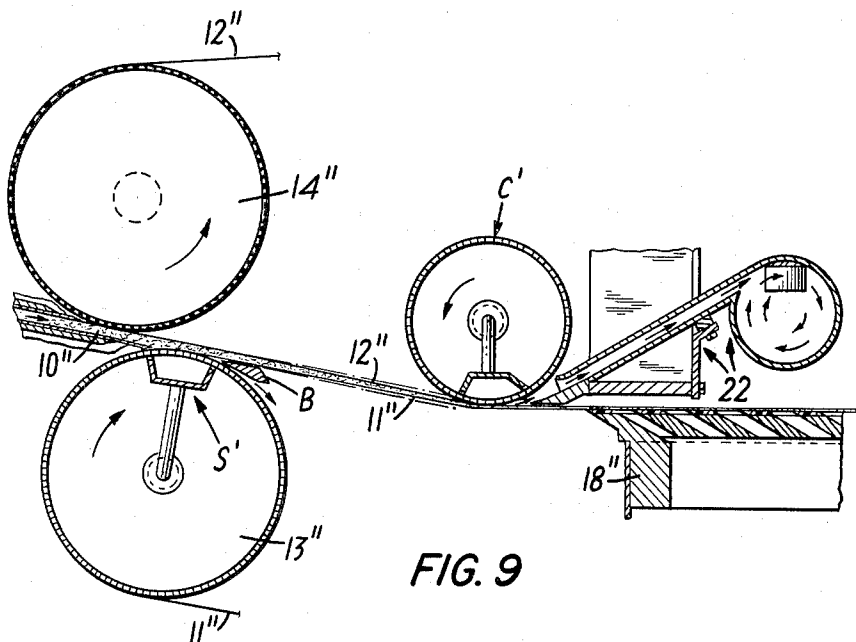


FIG. 9

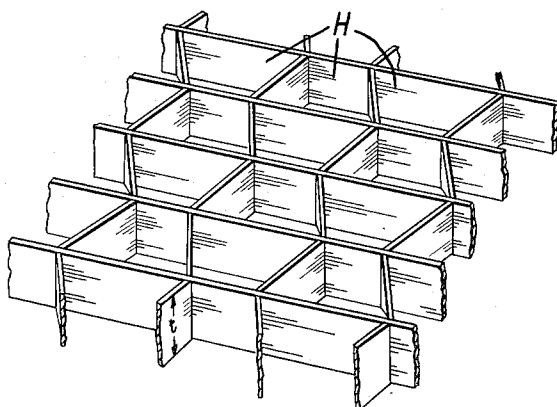


FIG. 10

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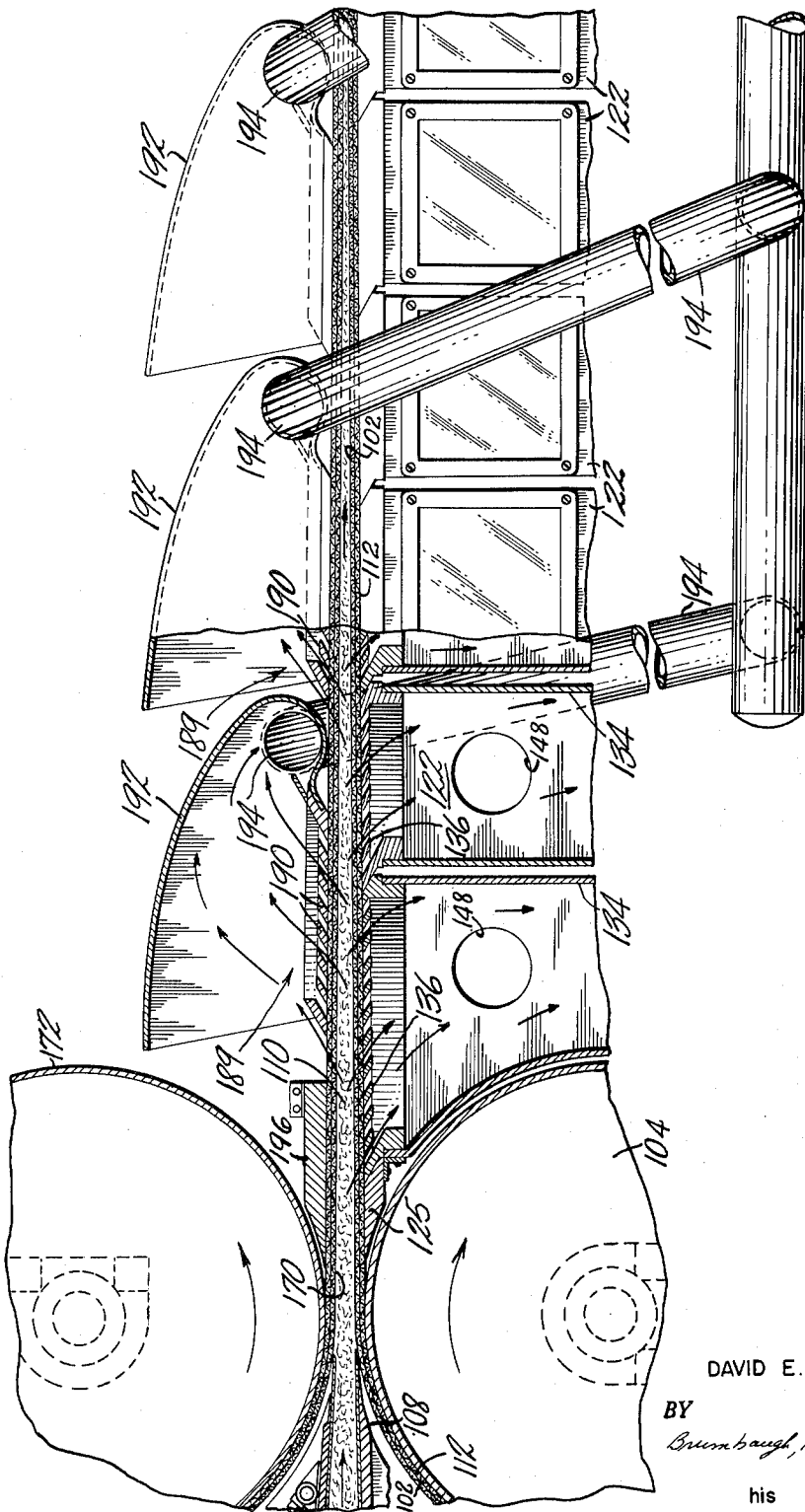


FIG. 11

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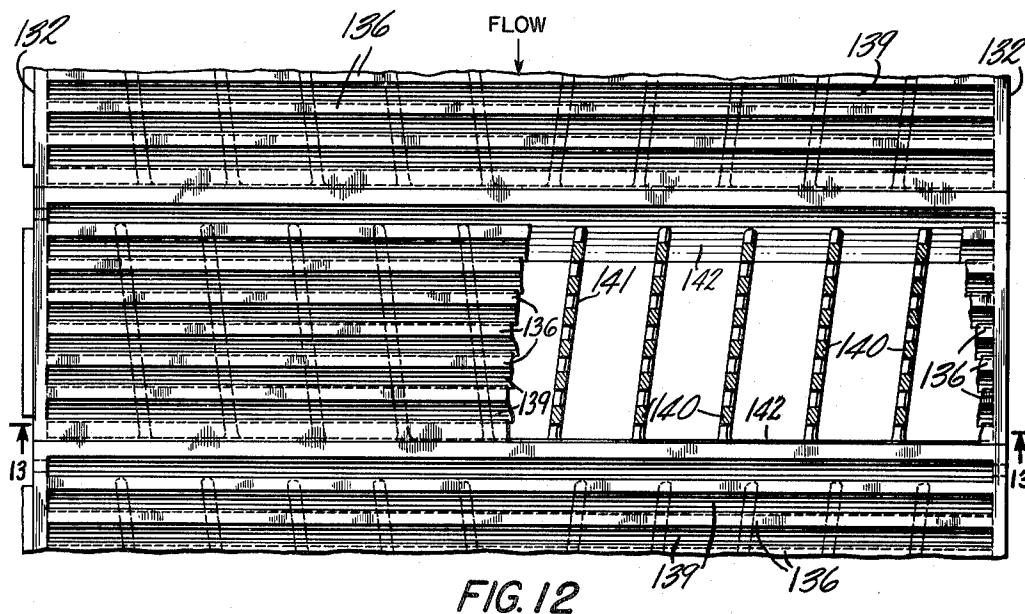


FIG. 12

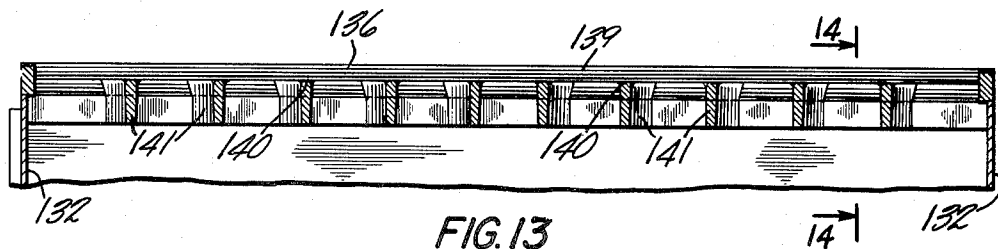


FIG. 13

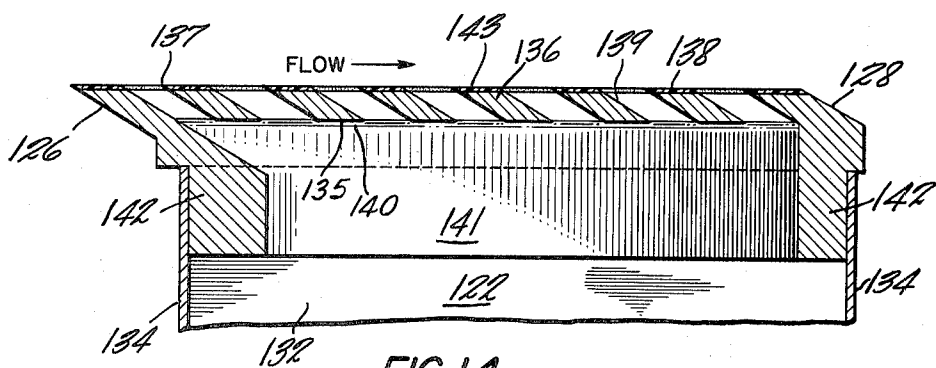


FIG. 14

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DUAL WIRE TYPE PAPER-FORMING APPARATUS AND METHODS OF FORMING AND DEWATERING PAPER

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Filed Sept. 16, 1963, Ser. No. 311,278
24 Claims. (Cl. 162-203)

This is a continuation-in-part of my applications Serial No. 1,261, filed January 8, 1960, for "Paper Former," now abandoned; Serial No. 45,858, filed July 28, 1960, for "Paper Making Machine and Process," now abandoned; Serial No. 140,778, filed September 26, 1961, for "Paper Making Machine and Process," now Patent No. 3,149,028; and Serial No. 171,364, filed February 6, 1962, for "Paper-Forming Apparatus and Methods," now abandoned.

This invention relates to paper forming and, more particularly, to novel and highly effective apparatus for and methods of receiving paper stock from a source such as a slice and removing the water from the stock without removing appreciable amounts of clay and fines along with the water and without disrupting the stock as it felts to form a web of paper.

Paper-forming apparatus typically comprises a pair of rolls and a Fourdrinier wire trained about the rolls and adapted to receive paper stock from a slice, facilitate drainage of water from the stock so that the stock felts to form a web of paper, and transport the web to a press section for further processing. While recent improvements in paper-forming apparatus have facilitated an increase in forming speed, they have given rise to water disposal problems, excessive loss of clay and fines from the stock, and frequent disruption of the web during the critical initial phases of the forming process.

A principal object of the present invention is to remedy the problems outlined above and to provide improved means for making paper, including paper of the highest quality. More particularly, an object of the invention is to provide means for gently removing large quantities of water from a paper stock substantially immediately after its discharge from a slice in such a way as to prevent malformation of the web or sheet. A further object of the invention is to provide means for disposing of the water as quickly as it is expressed from the stock.

These and other objects are accomplished by providing, in exemplary embodiments of the invention adapted for use in a paper-forming machine having a pair of opposed permeable belts such as Fourdrinier wires, one or more grating assemblies for establishing a controlled convergence of the belts over an appreciable length thereof adjacent to the slice, whereby water is gently, smoothly and continuously expressed from the stock carried between the belts, and a water-disposal means operated by the energy of translation of the rapidly-moving stock. In certain embodiments of the invention, cellular, dandy, or other open rolls adapted to facilitate removal of water expressed from the web may be employed.

An understanding of further particulars of the invention may be obtained from a consideration of the following detailed description of representative embodiments thereof in conjunction with the accompanying figures in the drawings, of which:

FIG. 1 is a simplified or somewhat schematic elevational view, partly in section, of a portion of paper-forming apparatus constructed in accordance with the invention;

FIG. 2 is a fragmentary sectional elevation showing an alternate arrangement of a portion of the apparatus of FIG. 1;

FIG. 3 is a plan view, partly broken away, of a pair of grating assemblies constructed in accordance with the

invention and adapted to establish a controlled convergence of a pair of permeable belts in a forming area closely spaced apart from a slice;

FIG. 4 is a view taken approximately along the line 4-4 of FIG. 3 and looking in the direction of the arrows;

FIG. 5 is a view taken approximately along the line 5-5 of FIG. 4 and looking in the direction of the arrows;

FIG. 6 is a simplified schematic elevational view, partly in section, of a portion of another embodiment of paper-forming apparatus constructed in accordance with the invention;

FIG. 7 is an enlarged view of a portion of the apparatus of FIG. 6, rotated for convenience in presentation through a small angle counterclockwise with respect to the orientation of FIG. 6;

FIG. 8 is a sectional elevational view of another representative embodiment of apparatus constructed in accordance with the invention for establishing a controlled convergence of a pair of permeable belts in a forming area closely spaced apart from a slice;

FIG. 9 is a simplified schematic elevational view, partly in section, of a portion of another embodiment of paper-forming apparatus constructed in accordance with the invention;

FIG. 10 is a fragmentary perspective view of the surface of a cellular roll adapted for use in accordance with the invention;

FIG. 11 is an elevational view, partly in section, of a portion of another paper former constructed in accordance with the invention;

FIG. 12 is a top plan view of one embodiment of a suction box illustrating a principle of construction in accordance with the invention;

FIG. 13 is a sectional view taken approximately along the line 14-14 of FIG. 13 and looking in the direction of the arrows.

FIG. 14 is a sectional view taken approximately along the line 14-14 of FIG. 13 and looking in the direction of the arrows.

FIG. 1 shows a jet of paper stock 10 ejected in the direction indicated by the arrow, preferably at high speed, from a slice (not shown) and directed between a pair of opposed permeable belts such as Fourdrinier wires 11 and 12 respectively trained about a pair of opposed breast rolls 13 and 14. The jet of stock 10 is typically thin (0.3 inches, for example, in the vertical dimension of FIG. 1) and substantially as wide in a direction normal to the plane of the figure as the rolls 13 and 14. The permeable belts or wires 11 and 12 permit passage therethrough of water from the jet of stock 10.

The roll 13 forms with a roll 15 mounted in spaced-apart relation thereto a belt or wire path, run, or reach along which the belt or wire 11 is adapted to travel in a direction from the roll 13 to the roll 15. Similarly, the roll 14 forms with a roll 16 mounted in spaced-apart relation thereto a second belt path in which the belt 12 is adapted to move from the roll 14 to the roll 16. The rolls 13, 14, 15 and 16 are adapted to rotate, and hence the belts 11 and 12 to move, in the directions indicated by the arrows respectively associated therewith at tangential speeds equal to one another and, preferably, to the speed of the jet of stock 10.

The rolls 15 and 16 may be in the opposed relation shown in FIG. 1 and, when in such relation, may but need not form a pressure nip for extracting additional water from the web. The rolls 15 and 16 should be open unless they are at a portion of the web which has achieved a dryness of 15% or a little more, in which case they may be solid. Alternatively, the rolls 15 and 16 may have their axes disposed in separate planes normal to the portions of the belts 11 and 12 between the rolls 13, 15

and 14, 16, the roll 15 either leading or lagging the roll 16. In any of the combinations described above, the belt 11 or 12 may turn on the roll 15 or 16, respectively, or it may continue in the same plane to a turning roll downstream of the roll 15 or 16.

As the stock proceeds through the forming zone or along the path between the rolls 13, 15 and 14, 16, water shows some tendency to drain downwardly therefrom under the influence of gravity, passing from the web-contacting side of the belt 10 of the opposite or water-drainage side. Typically, however, one or more suction boxes such as the suction box 18 are used to accelerate the drainage of water. In conventional paper-forming apparatus, a suction box so employed is likely to withdraw water from the stock so abruptly, even though little suction is applied, that fines and clay—which, owing to the necessarily low consistency of the stock at this stage, have not had an opportunity to become intimately associated with the larger fibers—are withdrawn along with the water. A suction box so employed may even rupture the web, inasmuch as the solids content of the web at the upstream suction box, particularly if the box is disposed adjacent to the breast roll, may not exceed three or four percent.

While retaining the advantages of suction boxes and similar devices, the present invention obviates the attendant disadvantages by providing, in one embodiment of the invention, one or more novel belt-converging means such as the grating assemblies 20 and 21. The grating assemblies 20 and 21 are mounted between rolls 13 and 14 on the one hand and 15 and 16 on the other and preferably as close as possible to the rolls 13 and 14. At a point closely spaced apart from (by a quarter of an inch, for example) and downstream or downwire of the belt-converging grating assemblies 20 and 21, a water-disposal means 22 is mounted. The water-disposal means 22 may but need not be opposed to the suction box 18 as shown.

The grating assemblies 20 and 21 are mounted on mounting means M to establish a gradual and controlled convergence of the belts 11 and 12 between the rolls 13, 14 and 15, 16. The convergence of the belts 11 and 12 is static or independent of the time dimension in that they converge, even when the machine is not in operation, after the fashion, for example, of a pair of non-parallel railroad tracks. Further, when the machine is in operation, successive segments of the belts 11 and 12, though not the belts as a whole, converge dynamically, as might, for example, a pair of airplanes. The belts thus may be said to converge quasi-dynamically, and they express water through the belts in the forming zone from their web-contacting sides to their opposite or water-drainage sides.

The water disposal means 22 establishes a spiral motion of the expressed water and is adapted to operate substantially completely full of water under a pressure generated automatically in a manner hereinafter described.

In general, any breast roll, such as those shown in FIGS. 6, 9, and 11, making substantial contact with the jet is preferably, though not necessarily, foraminous. Thus, preferably, solid breast rolls do not make substantial contact with the jet but are spaced apart from the jet.

The rolls 13 and 14 may be arranged with their axes in separate planes normal to the portions of the belts 11 and 12 between the rolls 13, 15 and 14, 16. In such case, the grating assemblies 20 and 21 may each be placed as close as possible to the rolls 13 and 14, respectively (FIG. 2), or in wholly-opposed relation.

Thus, as FIGS. 1 and 2 show, the paper-forming apparatus and method of the invention provide for the laying of a rapidly-moving jet of stock between two rapidly-moving belts without disturbing the jet, a rapid but controlled removal of substantial quantities of water from the stock to provide an undisrupted web, and the

use of suction and, if desired, pressure-nip means to secure maximum dryness of the web before it is delivered to the press section. The water expressed through the upper belt 12 by the grating assemblies 20 and 21 apparently exerts a pressure on the web tending to impede the escape of fines and clay through the upper belt 12. The suction and pressure-nip means do not act on the web until the felting process is substantially complete and therefore do not disrupt the web.

The partly-broken-away plan of FIG. 3 reveals that the grating assembly 20 comprises a mounting member or holding means 25 mounting a plurality of blades 26 for contact with the belt 11. Similarly, the grating assembly 21 comprises a mounting member or holding means 27 mounting a plurality of blades 28 for contact with the belt 12. The blades 26 and 28 may be formed of stainless steel especially where, for example, the belts 11 and 12 are made of nylon. Alternatively, they may be formed of a thermosetting plastic made from fabric or paper impregnated with phenol-formaldehyde resins and compressed under heat into a permanently solid substance with good structural properties. One such substance is sold by Westinghouse Electric Corp. under the trademark "Micarta."

The blades 26 and 28 may be about $\frac{1}{16}$ " or less thick in a horizontal direction transverse to the direction of stock flow and are disposed in planes parallel to one another and normal to the portions of the belts 11 and 12 between the rolls 13, 15 and 14, 16. The planes of the blades 26 may be equally spaced apart a distance of about $\frac{1}{4}$ "; the planes of the blades 28 are preferably spaced apart the same distance. As a copending application by David E. Robinson and James Moran, Serial No. 303,473, filed August 19, 1963, for "Offset Grating Assemblies for Dewatering a Paper Web," discloses, the plane of each blade 26 or 28 (except the two end blades, each being represented in FIG. 3 as a blade 28) may be interposed between the planes of adjacent blades 28 or 26, respectively. This offset relation of the blades is claimed in said application Serial No. 303,473 and not in the present application. Further, in order to prevent shadow marking of the web, the blades 26 and 28 should form a small angle, preferably considerably less than 30° , with the direction of travel of the portions of the belts 11 and 12 between the rolls 13, 15 and 14, 16. For example, where the blades 26 and 28 are, say, 10" to 24" in length and $\frac{1}{16}$ " thick, one end may be displaced from the other $\frac{1}{4}$ " to $\frac{9}{10}$ " or slightly more in a direction transverse to the direction of motion of the portions of the belts 11 and 12 between the rolls 13, 15 and 14, 16, so that an end of one blade barely overlaps the opposite end of an adjacent blade.

FIG. 4 shows more clearly than FIG. 1 that the surfaces or edges 30 and 31 of the blades 26 and 28 which contact the belts 11 and 12, respectively, converge in a direction from the rolls 13 and 14 to the rolls 15 and 16. In a typical case, the angle of convergence may be $\frac{1}{4}^\circ$ to 6° . For example, where blades having a length of 10" are employed, the vertical spacing between opposed edges 30 and 31 may be decreased from 0.3" at the upstream end to 0.03" at the downstream end.

As another example, where blades 24" in length are used, the gap between the wires 11 and 12 may converge from .312" at the upstream ends of the blades 26 and 28 to .047" at the downstream end of the blades. The optimum degree of convergence depends to some extent on forming speed and other parameters, as workmen skilled in the art will readily understand.

The edges 30 and 31 may, if desired, be contoured so that the rate of belt convergence is not constant along their length. For example, a slight convexity of the edges 30 and 31 towards the belts 11 and 12 may be desirable in many cases, so that the belts converge somewhat more rapidly in the vicinity of the upstream por-

tions of the blades 26 and 28 than in the vicinity of the downstream portions.

It can be seen from FIG. 5 that the blades 26 and 28 are adjustably mountable in slots 34 and 35 respectively formed in the holding means 25 and 27 and extending generally longitudinally of but forming a small angle with the portion of the belts 11 and 12 between the rolls 13, 15 and 14, 16. The blades may be secured in the slots by means of a suitable adhesive such as an epoxy resin 36. Thus, it is possible to contour not only individual edges 30 and 31 but also the loci of points of contact of successive edges 30 or 31 with the belt 11 or 12, respectively, in a direction transverse to the direction of movement of the portions of the belts between the rolls 13, 15 and 14, 16. Normally, of course, the loci should lie in straight lines.

The spaces between the blades 26 and 28 form a plurality of ducts through which water expressed from the jet of stock 10 through the wires 11 and 12 passes prior to being removed by the scoops, suction boxes, or water-disposal means to be described hereinafter. In accordance with the invention, the total cross-sectional flow area of the web and water between the wires 11 and 12 and through the ducts between the blades 26 and the ducts between the blades 28 is preferably kept substantially constant so that the velocity of the web and water is likewise substantially constant. If the total cross-sectional flow area of the web and water is allowed to increase substantially, as for example, by the formation of a layer of water substantially thicker near the downstream end of the ducts between the blades 26 and the ducts between the blades 28 than at the upstream end, the resulting reduction of the velocity of the water may cause the water to rewet and occasionally to disrupt the web.

A preferred means of the invention for preventing water slowdown is to limit the height of the ducts near the downstream end of the grating assemblies. In certain test runs of apparatus constructed in accordance with the invention, the depth of the blades—i.e., the distance between the inner surfaces of the blade holders and the inner surfaces of the blades—has been $\frac{1}{8}$ " at the upstream end of the grating assemblies and $\frac{1}{4}$ " at the downstream end. While the ducts between the blades are in such case deeper at the downstream end of the grating assemblies than at the upstream end, the total space occupied by the web and by the water expressed from the web may nevertheless be substantially constant, inasmuch as the grating assemblies may be so constructed and mounted that the ducts between the blades contain little or no water at their upstream end. The ducts thus define a portion of a flow path which flow path has a substantially constant cross-sectional area along the length of the blades. The remaining portion of the flow path is of course the space between the wires and in the interstices of the wires.

The relationships discussed in the preceding paragraph are illustrated in greater detail in FIGS. 6 and 7, which represent an alternate embodiment of the invention described in connection with FIGS. 1-5. The parts of the apparatus of FIGS. 6 and 7 corresponding to parts of the apparatus of FIGS. 1-5 are given primed reference numerals otherwise identical to those employed in FIGS. 1-5.

FIG. 6 shows permeable belts such as Fourdrinier wires 11' and 12', preferably of fine mesh, trained about conventional impervious breast rolls 13' and 14', respectively. The breast rolls 13' and 14' are adjustably elevated above the positions of the rolls 13 and 14 of FIGS. 1 and 2, so that the wires or permeable belts 11' and 12' between the breast rolls 13', 14', and a cellular or other open roll C form an angle, shown by way of example in FIG. 6 as about 15° , with respect to the portions of the wires 11', 12' downwire of the roll C in the plane of paper formation.

The stock 10' is ejected from a slice 108' which thoroughly mixes the fibers in the stock to obtain an even distribution of the fibers. The stock 10' ejected from the slice 108' enters between the rolls 13' and 14' at a speed preferably equal to the speed of the wires 11', 12'. The roll 13' may be in the same vertical plane as the roll 14' or may lead or lag that plane. Similarly, the roll 13' may be in the same plane normal to the plane of the jet of stock 10' between the rolls 13', 14' and the roll C as the roll 14' or may lead or lag that plane. Satisfactory results have been obtained with the center of the roll 13' about $1\frac{1}{2}$ " downwire of the vertical plane through the center of the roll 14'.

FIG. 7 shows a preferred structure for the grating assemblies 20' and 21' designed to prevent substantial slowdown of the water expressed from the jet of stock 10' through the wires or permeable belts 11' and 12'. (For convenience in presentation, the grating assemblies 20', 21' of FIG. 7 have been rotated approximately 15° counterclockwise from their orientations in FIG. 6.)

The thickness of the jet of stock 10' may be, in a typical case, of the order of .312" at the upstream end of the grating assemblies 20' 21' and of the order of .047" at the downstream end. Paper stock, being largely water, is of course practically incompressible and, if substantial slowdown of the water expressed from the stock is to be avoided, the cross-sectional flow area of the stock and water at the downwire end of the grating assemblies 20', 21' must be substantially the same as the cross-sectional flow area at the upwire end. It is desirable to maintain the cross-machine width (i.e., the dimension normal to the plane of FIG. 7) of the jet of stock 10' constant, and, in order to maintain the cross-sectional flow area substantially constant, the height thereof at the downwire end of the grating assemblies 20', 21' is preferably limited substantially to the height of the jet of stock 10' at the upwire end of the grating assemblies 20', 21' plus a small additional height which is a function of the displacement of the water by the blades 26', 28' and the wires 11', 12'. At the upwire end of the grating assemblies 20', 21', the wires 11', 12' and blades 26', 28' may be but are normally not immersed in the jet of stock 10'. At the downwire end immersion occurs, and the displacement of the water is a function of distance along the length of the grating assemblies 20', 21'.

FIG. 7 shows that the apparatus of the invention effectively restricts the cross-sectional flow area of the water near the downwire end of the grating assemblies 20', 21'. The water expressed from the web through the belts 11', 12' forms, above and below the wires, layers of water having outer boundaries W. Inasmuch as the outer boundaries or cross-sectional flow area of the water cannot expand beyond the inner surfaces of the blade holders 25' and 27', the velocity of the water cannot decrease substantially. Rewetting and disruption of the web are therefore prevented.

The fines retention of apparatus comprising the grating assemblies of FIGS. 6 and 7 exceeds that of apparatus comprising the grating assemblies of FIGS. 3-5 and is, in fact, about 80%.

Additional short blades (not shown) may be interposed between adjacent blades 26, 28 or 26', 28' at their upwire ends, but their use has been found unnecessary.

Owing to the elevated position of the rolls 13', 14' (FIG. 6) the wires or permeable belts 11', 12' partly wrap the cellular or other open roll C, applying pressure to the web in order further to consolidate it. Conduits, passages, or openings in the roll surface conduct water away from the stock and contain all of the expressed water or the excess water which cannot be rapidly handled and disposed of by suction boxes or other water-disposal means. While the water contained in the conduits or passages may be held therein by any means known to the art against feedback or reabsorption into the stock, it may, in particular, be drawn away by vacuum

until the roll surface is separated from the wires. Gravity may also in certain cases be utilized. The roll C (and the rolls C' and 13'' to be described hereinafter) may be of any suitable size. Other factors being the same, the greater the roll diameter, the greater the area of contact between the roll and wire.

The cellular roll C shown in FIG. 6 is provided with suction means S adapted to remove water expressed from the web through the wire 12' by the converging grating assemblies 20', 21' and by wrapping of the wires 11' and 12' about the roll C and discharge the water into water-disposal means 22'. The part of the suction means S in contact with the roll surface constitutes a form of stationary water-disposal means, and the roll surface a form of movable water-disposal means. Owing to the thickness t (see FIG. 10 of the present specification, *infra*) of the roll surface, the stationary water-disposal means S is widely spaced apart from the stock, so that white water impinging on the stationary water-disposal means does not splash on the web to disrupt it.

The suction developed by the suction means S need not be sufficient to withdraw and dispose of water through the air-suction line L, but need be sufficient only to divert the expressed water from the wire or belt 12' and channel or guide the water to the water disposal means 22'. Use of the roll is advantageous even where no suction is applied; in such case, especially where the cells or other openings in the roll surface are small, capillary action facilitates withdrawal of water from the web.

In accordance with the embodiment of the invention shown in FIG. 6, it is therefore possible to obtain the benefit in speed of water disposal facilitated by suction means without the attendant disadvantage of the danger of web disruption due to the use of excessive vacuum in the early stages of paper formation. Further, the water expressed through the lower wire 11' by the converging grating assemblies 20', 21' is readily diverted by gravity and inertia from the wires 11', 12' and presents no water-disposal problem.

The blade 43' of the water-disposal means 22' is preferably placed as close as possible to the roll C. A suction box 18' mounted on the opposite side of the permeable belts or wires 11', 12' from the water-disposal means 22' may have its leading wire-contacting edge opposed to the blade 43' but, preferably, has its leading wire-contacting edge downwire of the blade 43' by about $\frac{1}{2}$ inch as shown in FIG. 6.

FIG. 10 is a perspective fragmentary view of one form of roll surface suitable for the rolls C, C' and 13'' (FIGS. 6 and 9). The cells or passages H of FIG. 10 are, in plan or cross section, isosceles trapezoids disposed in rows parallel to first and second mutually substantially perpendicular axes, major and minor bases of the trapezoids being parallel to the first axis, being colinear, contiguous with one another, and alternated with one another along paths parallel to the first axis, and being alternated at substantially equal intervals along paths parallel to the second axis. (In the embodiment of the roll illustrated in FIG. 10, the "first" axis may be parallel to the axis of the roll, while the "second" axis may be in a plane normal to the roll axis. Other orientations of the axes are of course, possible within the scope of the invention.) From another standpoint, any two adjacent cells H with a major base in common have the shape of a hexagonal honeycomb cell divided by a wall bisecting one pair of opposite vertices of the honeycomb cell.

Other types of open rolls suitable for the purpose will readily suggest themselves to workmen skilled in the art. In particular, rolls having other cellular formations and dandy rolls are suitable. In all such constructions, the cells H or other openings in the roll surface preferably have a thickness t (FIG. 10) approximately equal to the depth of the layer of expressed water below or above the wire 11', 11'', 12', 12''; etc. More particularly, the cells H or other openings in the roll surface provide pores,

conduits, passages, or openings which in the aggregate have a volume sufficient to contain and rapidly to conduct away from the wires 11', 12'; 11'', 12''; etc., all of the water expressed from the web.

FIG. 9 shows one of a number of possible variations on the structures of FIGS. 6 and 7. In FIG. 9, the belt-converging grating assemblies 20', 21' are not employed, and the belt-converging function of the invention is performed by an open breast roll 13'' in cooperation with an upper breast roll 14''. The open breast roll 13'' is not tangent to the jet of stock 10'' but rather cuts into the jet of stock so that the lower wire 11'' converges on the upper wire 12'' to express water from the jet of stock 10''. The open roll 13'' is provided with suction means S' for the purpose of diverting the water so expressed from the jet 10''. A blade B mounted as close as possible to the open breast roll 13'' facilitates the diversion and disposal of the expressed water. The suction means S' is preferably similar to the suction means S shown in FIG. 6 and described in connection with that figure and need not be further described here.

An open roll C' is similar in construction and operation to the roll C of FIG. 6 and need not be further described here. Owing to the absence of grating assemblies in the embodiment of FIG. 9, the roll C' is preferably fairly close to the upper solid breast roll 14''. In test runs of the apparatus of FIG. 9, a separation between the adjacent surfaces of the rolls C' and 14'' of about $\frac{1}{2}$ '' has given satisfactory results.

A suction box 18'' and a water-disposal means 22'' are provided to express water through the wires 11'' and 12'', respectively.

The surfaces of the open rolls of the present invention, such as the rolls C, C', and 13'', constitute foraminous sheets. The foraminous sheets need not, however, be limited to the construction illustrated, inasmuch as the important function of the structure is its ability co-operatively to provide conduits having a volume sufficient for rapidly conducting all of the water away from the web that is being formed and, if necessary, containing such water.

The rolls C, C', and 13'' may be adjustably mounted or shiftable with respect to each other in order to provide for control of the contour of the forming zone.

The arrangements of FIGS. 6 and 9 will suggest many modifications to workmen skilled in the art. For example, the elevations of the breast rolls, shown as about 15° in FIG. 6 and as about 11° in FIG. 9, may be varied within wide limits. Likewise, the upper breast roll 14' or 14'' may be an open roll and may be provided with suction means. Further, the suction means in the rolls C, C', and 13'' may be omitted. Again, in the embodiment of FIG. 6, the grating assemblies 20' and 21' may be omitted and a roll similar to the roll C may be mounted beneath the lower wire 11' between the breast roll 13' and the roll C. In such case, the wires 11' and 12' may lap the roll, making a bend opposite to the bend they make in lapping the roll C. Many other modifications will suggest themselves to workmen skilled in the art.

In order to fabricate grating assemblies of the character described above (see, for example, FIGS. 3-5), it is necessary merely to form the slots 34 and 35 in the holding means 25 and 27 at appropriate intervals and adjustably insert the blades 26 and 28 in the respective slots 34 and 35. Adjustment of the blades 26 and 28 is effected by any suitable means. Only after the blades are properly adjusted is the epoxy 36 or other adhesive applied. Obviously, neither machining nor welding is necessary. The elimination of the welding requirement in accordance with the novel method of fabrication of the grating assemblies is particularly advantageous in that it facilitates the use of the stainless steel parts.

The grating assemblies 20 and 21 may be adjusted so that about 50% of the water they express from the stock passes through each of the belts 11, 12; 11', 12'; or 11'',

12". The water-disposal apparatus 22 or other water-disposal apparatus disposes of the water passing through the upper belt, and suction boxes facilitate disposal of the water passing through the lower belt. It is therefore unnecessary to drain the water completely through the web to the lower side thereof as in many conventional machines.

FIG. 12 is a top plan view of several adjacent suction boxes and shows the relationship of the blades 136 with respect to each other and drainage boxes 122 (FIG. 11). The arrows at the tops of FIGS. 12 and 14 indicate the direction of travel of the wire 102 and of the sheet carried thereby. The blades 136 are approximately $\frac{3}{16}$ " to $\frac{1}{4}$ " in thickness, and their flat top surfaces 138 (FIG. 14) extend about $\frac{3}{8}$ " to $\frac{1}{2}$ " in the direction of wire travel. Their flat bottom surfaces 135 have about the same width. The front and back surfaces 139 are of course parallel and form a dihedral angle with respect to the direction of wire travel of about 30° to 40°. The leading edges 137 are the lines of intersection between the leading surfaces 139 and the top surfaces 138. The centers of the blades are spaced from each other about $\frac{3}{4}$ " to about 1".

Such a construction offers the advantages that the translational energy of the sheet facilitates the removal of water therefrom, that maximum upper-blade-surface area is provided for supporting the wire and web, that sufficient area between the blades is provided to facilitate application of the desired suction to the web and drainage of water therefrom, and that undue wear of the leading edges of the blades is avoided. The spacing of the blades may be varied to some extent in accordance with forming speed, the degree of vacuum employed, and other factors.

As FIGS. 12-14 show, the elongated rectangular braces 141 are mounted on and extend between the side walls 134 and support the blades 136 by abutment at 140 with their lower surfaces 135. The braces 141 may be spaced apart from each other by about $\frac{1}{2}$ ", center to center, and are preferably angled with respect to the direction of travel of the wire. The angling of the braces in combination with the use of coarse and fine wires prevents shadowing of the paper. In large machines, the blades may be twenty feet or more in length, and, were it not for the support provided by the braces 141, the blades might suffer damage due to the high vacuum placed on the wire and sheet.

Other bracing arrangements may also be employed. For instance, spaced rods may be extended through the blades rather than beneath them. The rods or other braces may of course be angled with respect to the direction of travel of the wire to prevent their shadowing the sheet.

In making the suction boxes of the invention, a steel shell of the type shown in FIGS. 11-14, having first walls 132 and 134, may be first fabricated of sheet steel. The top may then be cast of a material such as an epoxy resin, bronze, or aluminum to form a rectangular frame 142 (FIG. 14) adapted to seat within and on the walls 134. The supports 141 are cast integrally with the frame 142. The blades 136 may be either cast integrally with the frame 142 and supports 141 or prefabricated separately of Micarta, bronze, aluminum, or other material having the required strength and then placed on the cast frame 142 and supports 141 prior to the setting or hardening of the frame and supports. Either process results in a welding of the blades 136 to the supports 141.

The blades may then be coated on their tops with a layer 143 of polytetrafluoroethylene (sold by the E. I. du Pont de Nemours & Co. under the trademark "Teflon") to provide a wire-supporting surface having a low coefficient of friction. Such a surface prevents undue wear of the blades 136 and traveling wire 102 and reduces the power required to operate the machine. Owing to the reduced power requirements, a large number of suction

boxes may be employed in accordance with the invention. Other low-friction materials may of course be used in place of polytetrafluoroethylene.

The frame 142 may be provided with adjusting means (not shown) co-operating with the walls 132 or 134 for obtaining a level belt-contacting surface.

In one embodiment of the invention, scraper blade assemblies 189 (FIG. 11) are mounted above the web-forming run of the upper wire or wires. The scraper blade assemblies 189 bear on the upper surface of the top wire 170 (or of another wire such as coarse wire run between the top wire 170 and the upper breast roll 172) and are adapted to use the energy of translation of the rapidly-moving stock to convey water from the top of the inchoate web. The portions of the blade assemblies in contact with the wire are similar to the tops of the suction boxes previously described and comprise a frame adapted to mount a plurality of blades 190 having leading surfaces forming an angle of about 30° with respect to the direction of wire travel. Each blade 190 may be constructed with an outer surface of polytetrafluoroethylene contacting the wire and may have dimensions similar to those of the blades 136 for the suction boxes 122. In particular, the blades 190 of the blade assemblies 189 may be spaced apart from each other about $\frac{3}{4}$ of an inch to an inch, center to center, and the assemblies 189 may have a length in the direction of wire travel of about 6 inches.

Further, the blade assemblies 189 may be provided with cross braces similar to those described above for the suction boxes. The cross braces may, of course, be angled with respect to the direction of pulp and wire travel to prevent shadowing of the pulp.

Scoops 192 mounted above and co-operated with the blade assemblies 189 are connected to water drainage lines 194 which are located at the downwire ends of the associated grating assemblies 189 and which are adapted to convey water away from the machine. At speeds of about 2,000 feet per minute, satisfactory results have been obtained using two or three such assemblies. A limit is placed on the number of blade assemblies which may be used by the fact that a filter-like layer or mat of pulp substantially impervious to water (unless suction, etc., is employed) is soon formed on the top of the sheet.

In accordance with another embodiment (not shown) of the invention, vacuum boxes similar to the boxes 122 are mounted adjacent to the upper surface of the top wire in the paper-forming zone in order to withdraw additional quantities of water. The blade assemblies, however, generally remove a sufficient amount of water and obviate the use of upper suction boxes.

An advantage of the use of blade assemblies in the manner described above is that they hold the top wire 170 (plus a coarse top wire, if used) firmly against the discharged pulp and prevent deflection of the wire or wires due to the pressure exerted thereon by the pulp. In providing, in combination with the lower suction boxes, a substantially continuous surface area for constraining the upper and lower wires, the blade assemblies greatly facilitate maintenance of proper sheet caliber.

A small forming board 196 may be mounted as shown in FIG. 11 adjacent to the upper breast roll 172 and closely spaced apart from and downwire of the nip formed by that roll and the lower breast roll 104. The forming board 196 prevents the air and water movement created by the rotation of the roll 172 from deflecting the wire 170. The leading edge of the forming board 196 is shaped complementally to the roll 172 and may be in contact with the surface of the roll.

FIG. 8 shows another embodiment of paper-forming apparatus constructed in accordance with the invention. Lower and upper breast rolls 201 and 202, which are preferably solid for greater rigidity, are mounted in spaced-apart relation (to prevent disruptive pumping of the stock by the rolls) to a jet of stock 203 discharged between the

rolls 201 and 202 by a slice 204. A permeable belt 205, which may be made of nylon, is wrapped about the lower roll 201, and another permeable belt 206, which may be a fine-mesh Fourdrinier wire, is also wrapped about the roll 201 and is on top of the wire 205. The upper roll 202 may similarly be provided with a fine-mesh wire 208 and, between the wire 208 and the roll 202, a belt 209, which also may be made of nylon. As shown, the jet of stock strikes the lower belts somewhat before it strikes the upper belts.

A short suction box 211 may be mounted below the lower belt 205 and adjacent to the lower roll 201. The suction box 211 is provided with a plurality of blades 212 extending transversely of the direction of movement of the foraminous elements 205, 206, 208, 209 therepast and having upper and leading faces which form acute dihedral angles with respect to each other. Reinforcing means such as a brace 213 reinforces the blades 212. A light suction may be applied through an exit 211' in the suction box 211. The nylon belts 205 and 209 and the suction box 211 may be omitted, in which case a grating assembly 215 may be mounted more closely to the roll 201.

The belt converging means of FIG. 8 is the curved stationary grating assembly 215. The grating assembly 215 comprises means such as one or more blades 216. The blades 216 have upper belt-contacting surfaces convexly cylindrically curved about at least one horizontal axis, and the permeable belts mounted in opposed relation with respect to each other and movable in a forming zone in substantially parallel paths for receiving therebetween the jet of paper stock 203 are trained about the surfaces in the forming zone and curved by the surfaces about the axis. The belts are thus made to converge in a controlled manner. The curvature of the blades 216 may be of uniform magnitude, and the blades may extend, for example, along a relatively small arc of a cylinder having a diameter of about 16 feet. The arc may be horizontal at its downstream end 215a and inclined say 20° upwardly towards its downstream end at its upstream end 215b. Thus, the slice 204 may be directed upwardly at an angle of about 20° and the jet of stock 203 curved through an arc of about 20° as it passes across the grating assembly 215 so that it emerges at a point 225 traveling in a horizontal direction.

The blades 216 may of course form a small angle with respect to the paths of the belts 205, 206, 208, and 209 to prevent shadow marking of the web.

A back-up plate or blade-mounting member 218 which supports the blade or blades 216 may be perforated or foraminous as shown. The foramina 219 permit the passage of water through the back-up plate 218 and into means such as a suction box 220. The foramina 219 may form a divergent angle with the paths of web movement in order to facilitate the removal of water from the web and through the foramina.

The suction box 220 may be provided with a plurality of vanes 221, curved either out of or into the plane of FIG. 8, to direct the expressed water to an exit 221' which communicates with a vacuum pump (not shown) whereby a vacuum, preferably light, may be applied to the web of stock as it passes over the grating assembly 215. In a wide machine, two pluralities of curved vanes may be provided, a first channeling the water expressed from the left half of the web to the left side of the machine and a second channeling the water expressed from the right half of the web to the right side of the machine. A scraper blade 227 removes water expressed through the upper wires 208, 209.

Thus, in accordance with the invention, novel and highly effective apparatus for and methods of commencing the removal of water from a stock in a forming area without removing appreciable amounts of clay and fines along with the water and without disrupting the stock as it felts to form a web of paper are provided. As compared to prior-art apparatus, the novel paper-forming ap-

paratus of the invention achieves a substantial reduction in the length of the forming area, and, simultaneously, a significant increase in the forming speed. The apparatus is furthermore inexpensive to manufacture and repair.

Many modifications in form and detail of the representative embodiments of the invention disclosed herein will readily occur to workmen skilled in the art. For example, while the grating assemblies 20 and 21 have been illustrated as including a plurality of blades 26 and 28 disposed in rows extending transversely of the belts 11 and 12, respectively, apparatus situated only at the edges of the belts or a single blade contacting each belt near, say, the center of the belt, effects the desired convergence if the belts are sufficiently narrow or are flexible only about axes parallel to the axes of the various rolls.

Also the apparatus described in connection with FIGS. 11-14 may be operated without a coarse wire, and the apparatus described in connection with FIGS. 6-10 may be operated with a coarse wire between the wires 11', 12' or 11'', 12'' and one or more of the rolls on which they turn.

Accordingly, the invention is to be construed as including all the modifications which fall within the scope of the appended claims.

I claim:

1. Apparatus comprising a breast roll, a permeable belt trained about said breast roll, having a web-contacting side and a water-drainage side, and defining a forming zone wherein a stock mixture is received and formed into a web, a foraminous roll mounted in spaced-apart relation to said breast roll and having a surface defining a foraminous sheet opposable to said water-drainage side through at least a portion of said forming zone, said permeable belt being trained about said foraminous roll, means for supplying said mixture to said web-contacting side in said forming zone, and means for removing water from said mixture in said forming zone, said foraminous sheet conducting the water away from said forming zone.

2. Apparatus comprising a first permeable belt having a web-contacting side and a water-drainage side, a second permeable belt having a web-contacting side and a water-drainage side, said belts being mounted with portions of said web-contacting sides in opposed relation and defining therebetween a forming zone wherein a stock mixture is received and formed into a web, a roll having a surface defining a foraminous sheet opposable to the water-drainage side of one of said belts through at least a portion of said forming zone, means for supplying said mixture between said web-contacting sides, and means for removing water from said mixture in said forming zone through said first and second belts, said foraminous sheet defining passages therein having a volume sufficient in the aggregate to contain substantially all of the water removed through said one of said belts.

3. In a Fourdrinier machine wet end comprising a first roll, a second roll spaced apart from said first roll, said first and second rolls defining a first run therebetween, a Fourdrinier wire trained about said first and second rolls and having a lower drainage side and an upper paper-supporting side in said run, a third roll closely spaced apart from and above the plane of said first run, a fourth roll spaced apart from said third roll and closely spaced apart from and above the plane of said first run, said third and fourth rolls defining a second run therebetween closely spaced apart from and substantially parallel to said first run, a foraminous belt trained about said third and fourth rolls and having an upper water-removal side and a lower paper-compressing side in said run, means for driving said Fourdrinier wire at a high speed over said first and second rolls and from said first roll to said second roll in said first run and for driving said foraminous belt at a high speed over said third and fourth rolls and from said third roll to said fourth roll in said second run, and discharge means for discharging a paper stock be-

tween said paper-supporting side and said paper-compressing side, the improvement comprising a plurality of scoops disposed above said water-removal side at locations between said discharge means and said fourth roll, said scoops having bottoms defining wire-engaging surfaces and defining open spaces adapted to pass water into said scoops, said surfaces and said open spaces having substantially equal total areas, and said scoops further having fluid-exit means formed therein, whereby water from said pulp passing through said open spaces into said scoops is conducted away from said paper stock through said fluid-exit means.

4. Apparatus comprising a plurality of stationary belt-converging blades having belt-contacting edges convexly curved about an axis and first and second permeable belts mounted in opposed relation with respect to each other and movable in a forming zone in substantially parallel paths for receiving therebetween a jet of paper stock, said belts being trained about said edges in said zone and curved by said edges about said axis.

5. Apparatus as defined in claim 4 in which said edges are generally parallel to said paths.

6. Apparatus as defined in claim 4 in which said edges form small angles with respect to said paths.

7. Apparatus comprising a plurality of belt-contacting blades having upper belt-contacting edges convexly cylindrically curved about a horizontal axis through an arc of approximately 20°, foraminous means for the stationary mounting of said blades, lower and upper permeable belts mounted in opposed relation with respect to each other and movable downstream in a forming zone in substantially parallel paths for receiving therebetween a jet of paper stock, said belts being trained about said surface in said zone and curved by said surface about said axis through said arc of approximately 20°, said arc being horizontal at its downstream end and inclined 20° upwardly towards its downstream end at its upstream end, and said foraminous means having passages therein forming a divergent angle with said paths and adapted to convey water away from said stock, and suction box means cooperating with said foraminous means for drawing water from said stock through said foraminous means.

8. A paper-making machine wet end comprising a breast roll, a movable foraminous conveyor trained about said breast roll and having a first side for conveying a layer of paper stock and a second side opposite to said first side, a foraminous roll mounted in spaced-apart relation to said breast roll and adjacent to said second side and movable with said foraminous conveyor at a velocity equal to that of said foraminous conveyor, said foraminous conveyor being trained about said foraminous roll, and stationary water-disposal means mounted adjacent to said foraminous roll on said second side of said foraminous conveyor in widely-spaced-apart relation to said layer of paper stock, said foraminous roll continuously conveying water from successive portions of said layer and discharging said water to said stationary water-disposal means.

9. In a method of forming paper, the steps comprising moving a pair of permeable paper-forming members in closely-spaced apart paper-making relation at substantially the same speed and in substantially the same direction through a paper-forming zone, introducing a paper stock between said members, training at least one of said members in a curved path in said forming zone about a permeable curved supporting surface, maintaining said supporting surface stationary, and withdrawing water from said stock through said supporting surface to facilitate formation of said stock into a paper web.

10. In a method of forming paper, the steps comprising moving a pair of paper-forming members in closely spaced-apart paper-making relation at substantially the same speed and in substantially the same direction through a paper-forming zone, introducing a

paper stock between said members, training both of said members in a curved path in said forming zone about a permeable curved supporting surface, one of said members being in contact with said supporting surface, maintaining the other of said members free of restraining means in contact therewith at locations opposite said supporting surface, maintaining said supporting surface stationary, and withdrawing water from said stock through said supporting surface to facilitate formation of said stock into a paper web.

11. In paper-forming apparatus having a pair of permeable paper-forming members adapted to move in a given direction through a forming zone at substantially the same speed in opposed relation and to receive therebetween a paper stock for forming into a paper web, the improvement comprising first and second pluralities of blades, each blade of said first plurality of blades having an edge adapted to contact said first forming member in said forming zone and each blade of said second plurality of blades having an edge adapted to contact said second forming member in said forming zone, and blade-mounting means for mounting said blades with said edges extending generally in said direction and said edges of said blades of said plurality of blades collectively in converging relation to said edges of said blades of said second plurality of blades, whereby said blades force said forming members towards each other as said forming members proceed through said forming zone and facilitate expression of whitewater from said stock and formation of said stock into a paper web.

12. Apparatus as set forth in claim 11 in which said first plurality of blades is opposed to said second plurality of blades.

13. Apparatus as set forth in claim 11 further comprising first and second breast rolls, said first and second permeable members being trained about said first and second breast rolls, respectively, and said first plurality of blades being closely spaced apart from said first breast roll and said second plurality of blades being closely spaced apart from said second breast roll.

14. Apparatus as set forth in claim 11 in which said first and second pluralities of blades are disposed, respectively, in first and second rows extending across said first and second permeable members substantially transversely of said direction.

15. Apparatus as set forth in claim 11 in which each blade forms an acute angle with said direction.

16. Apparatus as set forth in claim 11 in which said forming zone lies substantially in a horizontal plane and said blades lie substantially in vertical planes.

17. Apparatus as set forth in claim 11 in which said edges are curved.

18. Apparatus as set forth in claim 11 in which the blades of said first plurality of blades define at least one duct therebetween, said duct defining a portion of a flow path which has a substantially constant cross-sectional area along the length of the blades of said first plurality of blades.

19. In paper-forming apparatus having first and second breast rolls and first and second permeable paper-forming members respectively trained about said breast rolls and adapted to move in a given direction through a forming zone substantially at the same speed in opposed relation and to receive therebetween a paper stock for forming into a paper web, the improvement comprising a foraminous roll mounted in spaced apart relation to said breast rolls for contact with one of said forming members in said forming zone, both of said forming members being trained about said roll, whereby said foraminous roll facilitates convergence of said forming members as said forming members proceed through said forming zone, expression of whitewater from said stock and into said foraminous roll, and formation of said stock into a paper web.

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20. Apparatus as set forth in claim 19 further comprising first and second pluralities of blades, each blade of said first plurality of blades having an edge adapted to contact said first forming member in said forming zone and each blade of said second plurality of blades having an edge adapted to contact said second member in said forming zone, and blade-mounting means for mounting said first plurality of blades between said foraminous roll and said first breast roll and said second plurality of blades between said foraminous roll and said second breast roll with said edges extending generally in said direction and said edges of said blades of said first plurality of blades collectively in converging relation to said edges of said blades in said second plurality of blades, whereby said blades further facilitate convergence of said forming members as said forming members proceed through said forming zone, expression of whitewater from said stock, and formation of said stock into a paper web.

21. Apparatus for forming paper comprising first and second belt-training means mounted in spaced-apart relation to each other, there being a first belt path therebetween, third and fourth belt-training means mounted in spaced apart relation to each other, there being a second belt path therebetween, said first and second belt paths being at least in part closely spaced apart from and generally parallel to each other, a first permeable belt trained about said first and second belt-training means and having a portion lying in said first path, a second permeable belt trained about said third and fourth belt-training means and having a portion lying in said second path, said portions defining a forming zone, means connected to said first and second belts for driving said first belt over said first and second belt-training means and from said first belt-training means to said second belt-training means in said first path and said second belt over said third and fourth belt-training means and from said third belt-training means to said fourth belt-training means in said second path, said portions moving at least in part generally in the same direc-

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tion, and permeable, stationary, curved belt-converging means contacting at least one of said belts in said forming zone to establish a quasi-dynamic convergence of said portions.

22. Apparatus as set forth in claim 21 in which said belt-converging means is elongated in said direction.

23. Apparatus as set forth in claim 21 in which said belt-converging means is elongated in said direction and in which the other of said belts is free of restraining means in contact therewith at locations opposite said one belt-converging means.

24. Apparatus as set forth in claim 21 in which said belt-converging means is substantially elongated in said direction and establishes a curvature of the path of motion of both of said portions of said belts to express water through said portions of said belts and through said belt-converging means and form a paper web, the other of said belts being free of restraining means in contact therewith at locations opposite said belt-converging means.

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